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(54) **Pattern exposing method using phase shift**

Belichtungsverfahren mit Phasenverschiebung

Méthode d'exposition utilisant le décalage de phase

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EP 0 534 463 B1

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a pattern exposing method which forms a resist pattern for the purpose of producing a semiconductor device.

[0002] Recently, the operation speed and integration density of semiconductor devices have increased considerably, and the size of the semiconductor devices has been reduced accordingly. For this reason, there are demands to form a fine pattern exceeding a resolution limit of the conventional patterning apparatus using an optical system, that is, the resolution limit of an imaging optical system of a wafer stepper, for example.

[0003] First, a description will be given of the general operation of a conventional demagnification projection exposure apparatus, by referring to FIG. 2 to 8.

[0004] A light from a light source such as a mercury lamp is irradiated on a reticle 1. The reticle 1 has a reticle pattern in which a chromium (Cr) light blocking layer 3 is formed on a glass substrate 2, so as to expose a hole having a rectangular shape corresponding to the rectangular shape of the light blocking layer 3. The reticle pattern is reduced by a demagnification projection lens 4 and is imaged on a wafer 5 so as to expose a positive resist on the wafer 5.

[0005] FIG.2 is a diagram for explaining the light intensity of the exposure light on the positive resist. FIG.2 (a) shows a partial cross section of the reticle 1. FIG.2 (b) shows the light amplitude distribution on the positive resist of the wafer 5 for the case where the exposure is made using the reticle 1. FIG.2 (c) shows the light intensity distribution on the positive resist of the wafer 5 for the case where the exposure is made using the reticle 1.

[0006] When the exposure is made by the light transmitted through the reticle 1 having the rectangular light blocking layer 3, the light intensity distribution on the positive resist of the wafer 5 has a negative peak having a relatively gradual slope. Hence, it is impossible to form a fine pattern which has a narrow width using such a light intensity distribution. In order to form a fine pattern which has a narrow width, it is necessary to make the slope of the negative peak sharper than that of the light intensity distribution shown in FIG.2 (c).

[0007] For example, if the exposure light is an i-line having a wavelength of 0.365 μm and the numerical aperture of the optical system is 0.50, the resolution limit is approximately 0.4 μm.

[0008] The slope of the negative peak of the light intensity distribution shown in FIG.2 (c) is dependent on the resolution of the imaging optical system. The resolution of the imaging optical system is determined by the exposure wavelength, the numerical aperture, the inconsistent performance of each individual lens itself and the like.

[0009] Accordingly, when the conventional demagnification projection exposure apparatus is used, it is impossible to form a fine hole which exceeds the resolution limit of the imaging optical system, and there is a problem in that the conventional demagnification projection exposure apparatus cannot cope with the patterns of the semiconductor devices which are becoming finer as the integration density is improved.

[0010] In order to eliminate the above described problem, the so-called phase shift method has been proposed. According to the phase shift method, the phase of the light transmitted through the reticle is shifted by a phase shift layer, so as to improve the resolution and contrast of the exposed image on the resist.

[0011] FIG.3 shows the imaging optical system of the demagnification projection exposure apparatus and the reticle used when carrying out the phase shift method. In FIG.3, those parts which are the same as those corresponding parts in FIG.1 are designated by the same reference numerals, and a description thereof will be omitted.

[0012] In FIG.3, a phase shift reticle 6 is used in place of the reticle 1 shown in FIG.1. The phase shift reticle 6 is made up of the glass substrate 2 and a phase shift layer 7 which is formed on the glass substrate 2.

[0013] FIG.4 is a diagram for explaining the light intensity of the exposure light on the positive resist when the phase shift reticle 6 is used. FIG.4 (a) shows a partial cross section of the phase shift reticle 6. The pattern which is to be exposed is formed by an edge part of the phase shift layer 7 which is formed on the glass substrate 2 of the phase shift reticle 6. A transmitted light 8' which has passed through the glass substrate 2 and the phase shift layer 7 has a phase which is shifted by 180° (π) with respect to a transmitted light 8 which has passed through only the glass substrate 2.

[0014] FIG.4 (b) shows the light amplitude distribution on the resist of the wafer 5 when the exposure is made using the phase shift reticle 6. As shown, the light amplitude becomes zero at a position of the resist corresponding to the edge part of the phase shift layer 7, and the light amplitude sharply reverses on both sides of the edge part.

[0015] FIG.4 (c) shows the light intensity distribution on the resist of the wafer 5 when the exposure is made using the phase shift reticle 6. Because the light intensity is proportional to the square of the light amplitude, the light intensity sharply becomes zero at a position of the resist corresponding to the edge part of the phase shift layer 7. Accordingly, it is possible to form on the resist a fine line-and-space pattern which has satisfactory resolution and contrast.

[0016] An example of a fine pattern formed by the phase shift method will be described with reference to FIG.5. FIG.5 (a) shows a plan view of the phase shift reticle 6 which has a square phase shift layer 7. FIG.5 (b) shows a fine resist pattern 10 which is formed by the edge part of the phase shift layer 7 of the phase shift reticle 6 shown in FIG.5 (a). As shown in FIG.5 (b), the fine

resist pattern 10 is formed at the side part of the square, that is, along a part on the resist corresponding to the edge part of the phase shift layer 7.

[0017] On the other hand, the phase shift layer 7 may be arranged in a checker board pattern in the plan view as shown in FIG.6 (a). When the phase shift reticle 6 having the phase shift layer 7 shown in FIG.6 (a) is used for the exposure, it is possible to form a resist pattern 10 which has edges with a fine contrast over a relatively large area as shown in FIG.6 (b).

[0018] However, when the phase shift reticle 6 described above is used for the exposure, it is impossible to pattern a cut part indicated by a dotted line in FIG.5 (b). In other words, the edge part of the phase shift layer 7 inevitably takes a closed contour (or loop), and there is a problem in that the actual patterns of integrated circuits (ICs) cannot be formed using the phase shift reticle 6.

[0019] Accordingly, in order to overcome this problem of the phase shift method, a modified method has been previously proposed to form the resist pattern using a phase shift reticle which has two kinds of phase shift layers as shown in FIG.7. FIG.7 (a) shows a plan view of the resist pattern which is to be formed.

[0020] FIG.7 (b) shows a plan view of the previously proposed phase shift reticle 6. This phase shift reticle 6 has the phase shift layer 7 for shifting the phase of the exposure light by 180° (π) at the edge part which is used for the pattern forming, and a phase shift layer 12 for shifting the phase of the exposure light by 90° ($\pi/2$). This phase shift layer 12 is provided adjacent to the phase shift layer 7 at a part where no pattern forming is made, that is, at a part where the pattern is to be cut. A region indicated by hatchings in FIG.7 (b) is the region of the phase shift layer 7 which shifts the phase of the exposure light by 180°. On the other hand, a region indicated by dots in FIG.7 (b) is the region of the phase shift layer 12 which shifts the phase of the exposure light by 90°. Unmarked regions other than the hatched and dotted regions are the regions of the glass substrate 2.

[0021] By appropriately setting the exposure condition or the developing condition of the resist, only the edge part formed by the phase shift layer 7 and the glass substrate 2 as shown in FIG.7 (c). Other parts, that is, the edge part formed by the phase shift layers 7 and 12 and the edge part formed by the phase shift layer 12 and the glass substrate 2, are not patterned. The edge part formed by the phase shift layer 12 and the glass substrate 2 is indicated by a dotted line in FIG.7 (c).

[0022] However, this previously proposed modified phase shift method has a problem in that it is extremely difficult in actual practice to realize the phase shift reticle 6 having the phase shift layers 7 and 12 which are finely shaped as described. Accordingly, there are demands to realize a more feasible phase shift method which can form fine resist patterns.

[0023] In Japanese Journal of Applied Physics, vol. 30. no. 5, May 1991, pages 1131 - 1136 a new optical lithography technique called outline pattern transfer imaging (OPTIMA) is described. OPTIMA utilizes an optical phase change at a clear phase-shifter pattern edge. Very narrow closed patters can be delineated along the fringe of the phase-shifter pattern by this method. The resolution limitation of OPTIMA is presented using a newly developed high-resolution i-line negative resist. The resist is transparent and has a high γ value. Practical focus latitude and exposure latitude are obtained for 0.2 μm patterns. In OPTIMA, linewidth control is also possible by adding notch patterns at the shifter edge.

[0024] It is the object of the present invention to provide a pattern exposing method enabling a high resolution.

[0025] The object is solved by the features of claim 1.

[0026] It is the concept of the present invention to provide a pattern exposing method for forming a predetermined resist pattern on a substrate, comprising the steps of (a) exposing a first resist layer which is formed on the substrate using a first reticle which includes a first pattern for exposing a first corresponding pattern on the first resist layer by use of a phase shift of light transmitted through the first reticle, (b) developing the exposed first resist layer, (c) forming a second resist layer on the entire surface of the substrate including a top of the first resist layer, (d) exposing the second resist layer using a second reticle which has a second pattern for exposing a second corresponding pattern on the second resist layer by use of light transmitted through the second reticle, where the second corresponding pattern overlaps at least a part of the first corresponding pattern, and (e) developing the second resist layer so that a part of the first corresponding pattern is removed by the second corresponding pattern and the predetermined resist pattern is formed. According to the pattern exposing method of the present invention, it is possible to form extremely fine patterns and holes which exceed the resolution limit of the imaging optical system and could not be formed by the conventional techniques.

[0027] Other objects and further features of the present invention will be apparent from the following detailed description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

FIG.1 is a diagram for explaining a pattern exposing method which does not fall within the scope of the appended claims.

FIG.2 is a diagram for explaining an exposure light intensity on a resist using the conventional reticle;

FIG.3 generally shows an imaging optical system of a conventional demagnification projection exposure

apparatus using a phase shift method and a conventional phase shift reticle;

FIG.4 is a diagram for explaining an exposure light intensity on a resist of the conventional phase shift reticle;

FIG.5 is a diagram for explaining a resist pattern formed by the conventional phase shift reticle;

FIG.6 is a diagram for explaining another resist pattern formed by the conventional phase shift reticle;

FIG.7 is a diagram for explaining a previously proposed modified phase shift method using a phase shift reticle having two kinds of phase shift layers;

FIG. 8 generally shows an imaging optical system of a conventional demagnification projection exposure apparatus and a conventional reticle;

FIG.9 is a diagram for explaining a pattern when cutting the pattern, this example not falling within the scope of the appended claims.

FIG.10 is a diagram for explaining a pattern exposing method, this example not falling within the scope of the appended claims.

FIG.11 is a diagram for explaining a pattern exposing method, this example not falling within the scope of the appended claims.

FIG.12 is a diagram for explaining a first embodiment of the pattern exposing method according to the present invention;

FIGS.13 and 14 are diagrams for explaining a second embodiment of the pattern exposing method according to the present invention;

FIG.15 is a diagram for explaining a third embodiment of the pattern exposing method according to the present invention;

FIG.16 is a diagram for explaining a fourth embodiment of the pattern exposing method according to the present invention;

FIG.17 is a diagram for explaining a fifth embodiment of the pattern exposing method according to the present invention;

FIGS.18 and 19 are diagrams for explaining a sixth embodiment of the pattern exposing method according to the present invention;

[0029] A description will be given of an example of a pattern exposing method, by referring to FIG. 1. This example does not fall within the scope of the appended claims.

[0030] FIG.1 (a) shows a plan view of a phase shift reticle 6 which is used in this embodiment. A phase shift layer 7 is formed on a glass substrate 2, similarly as in the conventional case where the resist pattern shown in FIG.7 (a) is to be formed. The optical system shown in FIG.3 is used to make a first demagnification projection exposure on a positive resist which is formed on a wafer 5 (not shown in FIG.1) using the phase shift reticle 6. During this first exposure, an edge part A which is indicated by a bold line in FIG.1 (a) is also exposed although this edge part A should not be exposed.

[0031] Next, a second demagnification projection exposure is made using a reticle 14 which has an opening 16 formed in a Cr light blocking layer 18 on a glass substrate 2, as shown in FIG.1 (b). Non-exposed parts 20, 22 and 24 which are not exposed during the first exposure exist on the resist at parts corresponding to the edge part of the phase shift layer 7. Out of these non-exposed parts 20, 22 and 24, the non-exposed part 20 is exposed during the second exposure. The opening 16 is provided in the reticle 14 in order to expose this non-exposed part 20.

[0032] The second exposure is made similarly to the demagnification projection exposure described above with reference to FIG.8, after aligning the reticle 14 to the resist pattern which is formed by the first exposure. When the second exposure is made, the positive resist on the wafer 5 at a part corresponding to an area within the opening 16 of the reticle 14 is exposed twice and is thus removed by a developing process which is carried out thereafter. As a result, a resist pattern corresponding to the edge part A which is indicated by the bold line in FIG.1 (a) is not formed, and the resist pattern is cut at a predetermined position as indicated in FIG.1 (c).

[0033] Next, a description will be given of the matters to be considered in this example, such as the alignments of the phase shift reticle 6 used during the first exposure and the reticle 14 used during the second exposure, by referring to FIG.9.

[0034] FIG.9 (a) is a diagram for explaining a minimum width to be cut and the like to be considered when cutting the resist pattern in this example. When cutting in two exposures a pattern 30 and a pattern 32 which are non-exposed parts before the resist is developed, a minimum width B to be cut must be made larger than the resolution which is determined by the normal reticle 14 which uses an opening in the light blocking layer for the exposure and the conventional imaging optical system shown in FIG.8. In addition, a distance C from an edge of the pattern 32 to a contact hole forming part 36, for example, must be determined by taking into account not only the above resolution but also an alignment error of the reticle 14. A distance from an edge of the pattern 30 to a contact hole forming part 34 must be determined similarly. Furthermore, a pattern width of the fine pattern which is actually formed spreads by approximately 0.1 μm from the edge of the phase shift layer 7, and this spread is approximately proportional to a value λ/NA of the optical system, where λ denotes the wavelength of the exposure light and NA denotes the numerical aperture of the optical system.

[0035] In other words, a width G of a contact part of the pattern 32 which is exposed on the resist as shown in FIG.9 (c) is greater than a width F of an edge part forming the contact part as shown in FIG.9 (b). In addition, an alignment error of the two reticles 6 and 14 is approximately 0.15 μm. This alignment error depends on the accuracy of the mask and the accuracy of the

alignment mechanism. Accordingly, when aligning the phase shift reticle 6 and the reticle 14, it is necessary to set a distance D between an edge of the contact part forming part of the phase shift layer 7 of the phase shift reticle 6 and a corresponding edge of the opening 16 of the reticle 14 to approximately 0.1 to 0.25 μm, so that the edge part of the contact part of the pattern 32 on the resist will not be removed by the second exposure which uses the reticle 14.

[0036] By making the first and second exposures using the two kinds of reticles, namely, the phase shift reticle 6 and the reticle 14, it becomes possible to easily form an extremely fine resist pattern shown in the plan view of FIG.9 (a).

[0037] Next, a description will be given of a pattern exposing method, by referring to FIG.10. This example does not fall within the scope of the appended claims. In FIG.10, those parts which are the same as those corresponding parts in FIG.1 are designated by the same reference numerals, and a description thereof will be omitted.

[0038] In this example, the resist pattern is basically formed similarly to the first example. The difference between the first and second example is that the resist pattern formed by the second example has a plurality of cuts, as in the case of the actual patterns used in the semiconductor device.

[0039] FIG.10 (a) shows a plan view of the phase shift reticle 6 which is used for the first exposure and the reticle 14 which is used for the second exposure in an overlapped state. In FIG.10 (a), a part surrounded by a dotted line corresponds to an area which is exposed by the second exposure using the opening 16.

[0040] FIG.10 (b) shows a completed pattern 10 which is completed by cutting appropriate parts of the pattern which is formed by the edge part of the phase shift layer 7 of the phase shift reticle 6 shown in FIG.10 (a) during the first exposure by the making the second exposure using the opening 16 of the reticle 14. As may be readily understood from the description above, it is possible to form an extremely fine resist pattern having a plurality of cuts using the double exposure.

[0041] Next, a description will be given of a pattern exposing method, by referring to FIG.11. In FIG.11, those parts which are the same as those corresponding parts in FIG.10 are designated by the same reference numerals, and a description thereof will be omitted.

[0042] In this example, which does not fall within the scope of the appended claims, = the resist pattern is basically formed similarly to the second example. In other words, the resist pattern formed by the third example has a plurality of cuts, as in the case of the actual patterns used in the semiconductor device.

[0043] FIG.11 (a) shows a plan view of the phase shift reticle 6 which is used for the first exposure and the reticle 14 which is used for the second exposure in an overlapped state. In FIG.11 (a), a part surrounded by a dotted line corresponds to an area which is exposed by the second exposure using the opening 16.

[0044] FIG.11 (b) shows a completed pattern 10 which is completed by cutting appropriate parts of the pattern which is formed by the edge part of the phase shift layer 7 of the phase shift reticle 6 shown in FIG.11 (a) during the first exposure by the making the second exposure using the opening 16 of the reticle 14. As may be readily understood from the description above, it is possible to form an extremely fine resist pattern having a plurality of cuts using the double exposure.

[0045] When forming a circuit pattern having a large integration density, the resist pattern becomes complex as shown in FIG.11 (b). Hence, the edges of the phase shift layer 7 of the phase shift reticle 6 which is used during the first exposure become very close to each other. In addition, the number of parts where the resist pattern must be cut is large. However, as long as the phase shift reticle 6 used for the first exposure and the reticle 14 used for the second exposure are aligned correctly, it is possible to easily cut the resist pattern at the large number of parts using the double exposure because the opening 16 in the light blocking layer 18 of the reticle 14 can be formed without difficulties using the existing technique.

[0046] As the line width of the pattern becomes finer, the pitch of the circuit patterns becomes narrower. However, it is possible to easily cope with this situation by the reticle 14 which is used for the second exposure and has the opening 16 formed in the light blocking layer 18 thereof. In the previously proposed modified phase shift method described above with reference to FIG.7 which requires two kinds of phase shift layers to be formed on the single substrate, it is extremely difficult technically to make a phase shift reticle on which a plurality of phase shift layers 7 and 12 coexist, thereby making this method unsuited for practical use. But according to this example, both the phase shift reticle 6 and the reticle 14 can be made with a sufficiently high accuracy using the existing techniques.

[0047] In the embodiments described above, the phase shift layer is formed on the glass substrate in a closed region which is surrounded by the edge part of the phase shift layer. However, this arrangement may be reversed so that the glass substrate forms the closed region and the phase shift layer is formed in a region other than the closed region of the glass substrate.

DESCRIPTION OF THE PREFFERED EMBODIMENTS

[0048] Next, a description will be given of a first embodiment of the pattern exposing method according to the present invention, by referring to FIG.12. In this embodiment, a resist pattern is formed for use in forming an extremely fine hole of the semiconductor device. More particularly, this embodiment uses the phase shift reticle 6 to form on a negative resist a resist pattern having a fine rectangular hole.

[0049] FIG.12 (a) shows a plan view of the phase shift reticle 6 which has the phase shift layer 7 formed on the glass substrate 2. This phase shift reticle 6 may be the phase shift reticle 6 shown in FIG.4, for example.

[0050] In FIG.12 (b) which shows a partial cross section of the wafer 5, a negative resist 39 is formed on the wafer 5 and a first demagnification projection exposure is made using the phase shift reticle 6 shown in FIG.12 (a). The negative resist 39 is developed after the first exposure, and a fine space pattern shown in FIG.12 (b) is formed in the negative resist 39 by the edge pattern of the phase shift layer 7 of the phase shift reticle 6 shown in FIG.12 (a).

[0051] Then, a negative resist 40 is formed on the entire top surface of the wafer 5 as shown in FIG.12 (c).

[0052] Next, a phase shift reticle 6 shown in FIG.12 (d) having a pattern which is rotated by 90° with respect to the phase shift reticle shown in FIG.12 (a) is used to make a second demagnification projection exposure. By developing the negative resist 40 after the second exposure, a fine space pattern is formed in the negative resist 40 by the edge pattern of the phase shift layer 7 of the phase shift reticle 6 shown in FIG.12 (d).

[0053] As a result, the fine space pattern formed in the negative resist 39 and the fine space pattern formed in the negative resist 40 intersect perpendicularly to each other, and a fine rectangular hole 41 shown in FIG.12 (e) is formed at the intersection.

[0054] For example, if the exposure light is the i-line and the numerical aperture of the optical system is 0.5, it is possible to make each side of the fine rectangular hole 41 approximately 0.2 μm. Therefore, by enabling the formation of such a fine hole, it becomes possible to further improve the integration density of semiconductor devices.

[0055] According to this embodiment, it is possible to sharpen the negative peak of the light intensity distribution on the resist by using the phase shift reticles 6 and making the first and second exposures. In other words, the line-and-space having a satisfactory resolution and contrast in the X direction and the line-and-space having a satisfactory resolution and contrast in the Y direction are formed by two independent exposures, and it is possible to form at the intersection of the two line-and-spaces a fine rectangular hole which cannot be formed by the existing technique using only one exposure. Therefore, the fine rectangular hole which is formed has sharp edges and the corners of the hole do not become rounded.

[0056] Next, a description will be given of a second embodiment of the pattern exposing method according to the present invention, by referring to FIGS.13 and 14.

[0057] FIG.13 (a) shows a plan view of a phase shift reticle 6 which is used in this embodiment. As shown, this phase shift reticle 6 has the regions where only the glass substrate 2 exist and the regions where the phase shift layer 7 is formed, in an alternate manner along the X and Y directions.

[0058] By forming the negative resist 39 on the wafer 5 and making a first demagnification projection exposure using the phase shift reticle 6 shown in FIG.13 (a) and developing the negative resist 39 after this first exposure, a fine space pattern 42 shown in FIG.13 (b) is formed by the edge pattern of the phase shift layer 7 of the phase shift reticle 6 shown in FIG.13 (a).

[0059] Next, the negative resist 40 is formed on the entire top surface of the wafer 5. Thereafter, the phase shift reticle 6 shown in FIG.13 (a) or the wafer 5 is moved as indicated by a dotted line in FIG.14 (a) so that the pattern of the phase shift reticle 6 shown in FIG.13 (a) is relatively shifted by x1 in the +X direction and by y1 in the -Y direction with respect to the wafer 5. From the point of view of improving the throughput of the lithography process, the above relative shift is desirably carried out by keeping the phase shift reticle 6 fixed and moving an X-Y stage which carries the wafer 5 and forms a part of the exposure apparatus.

[0060] Then, a second demagnification projection exposure is made using the same phase shift reticle 6 shown in FIG.13 (a), and the negative resist 40 is developed thereafter to form a fine space pattern 43 shown in FIG.14 (b) which is formed by the edge pattern of the phase shift layer 7 of the phase shift reticle 6. The fine space pattern 42 which is formed in the negative resist 39 and the fine space pattern 43 which is formed in the negative resist 40 intersect perpendicularly, and thus, fine rectangular hole 41 are formed at the intersections as shown in FIG.14 (c).

[0061] According to this embodiment, the fine rectangular holes which are formed have sharp edges and the corners of the holes do not become rounded.

[0062] Next, a description will be given of a third embodiment of the pattern exposing method according to the present invention, by referring to FIG.15.

[0063] In this embodiment, a phase shift reticle 6a which is shown in a plan view in FIG.15 (a) is used for the first exposure. This phase shift reticle 6a is made up of a glass substrate 2a, and a plurality of oblong phase shift layers 7a arranged in parallel on the glass substrate 2a.

[0064] Then, a phase shift reticle 6b which is shown in a plan view in FIG.15 (b) is used for the second exposure. This phase shift reticle 6b is made up of a glass substrate 2b, and a plurality of oblong phase shift layers 7b arranged in parallel on the glass substrate 2b. The direction in which the oblong phase shift layers 7b extend is perpendicular to the direction in which the oblong phase shift layers 7a of the phase shift reticle 6a extend.

[0065] Prior to making the first exposure, a negative resist 39 is formed on the wafer 5, similarly as in the case shown in FIG.12 (b), and the negative resist 39 is patterned by the first exposure using the phase shift reticle 6a shown in FIG.15 (a). As a result, fine space patterns 42 shown in FIG.15 (c) are formed in the negative resist 39 by the edge parts of the phase shift layers 7a.

[0066] Next, prior to making the second exposure, a negative resist 40 is formed on the entire top surface of the wafer 5, similarly as in the case shown in FIG.12 (c), and the negative resist 40 is patterned by the second exposure using the phase shift reticle 6b shown in FIG.15 (b). As a result, fine space patterns 43 shown in FIG.15 (c) are formed in the negative resist 40 by the edge parts of the phase shift layers 7b.

[0067] The fine space patterns 42 and the fine space patterns 43 intersect perpendicularly to each other. Thus, a fine rectangular hole 41 is formed at each intersection of the fine space patterns 42 and 43. In this embodiment, the fine rectangular holes 41 are simultaneously formed with the arrangement shown in FIG.15 (d).

[0068] Next, a description will be given of a fourth embodiment of the pattern exposing method according to the present invention, by referring to FIG.16.

[0069] In this embodiment, a phase shift reticle 6a which is shown in a plan view in FIG.16 (a) is used for the first exposure. This phase shift reticle 6a is identical to that used in the third embodiment.

[0070] Then, a phase shift reticle 6b which is shown in a plan view in FIG.16 (b) is used for the second exposure. This phase shift reticle 6b is made up of a glass substrate 2b, and a plurality of zigzag phase shift layers 7b arranged in parallel on the glass substrate 2b. The direction in which the zigzag phase shift layers 7b extend is perpendicular to the direction in which the oblong phase shift layers 7a of the phase shift reticle 6a extend.

[0071] Prior to making the first exposure, a negative resist 39 is formed on the wafer 5, similarly as in the case shown in FIG.12 (b), and the negative resist 39 is patterned by the first exposure using the phase shift reticle 6a shown in FIG.17 (a). As a result, fine space patterns 42 shown in FIG.17 (c) are formed in the negative resist 39 by the edge parts of the phase shift layers 7a.

[0072] Next, prior to making the second exposure, a negative resist 40 is formed on the entire top surface of the wafer 5, similarly as in the case shown in FIG.12 (c), and the negative resist 40 is patterned by the second exposure using the phase shift reticle 6b shown in FIG.16 (b). As a result, fine space patterns 43 shown in FIG.16 (c) are formed in the negative resist 40 by the edge parts of the phase shift layers 7b.

[0073] The fine space patterns 42 and the fine space patterns 43 intersect, and thus, a fine rectangular hole 41 is formed at each intersection of the fine space patterns 42 and 43. In this embodiment, the fine rectangular holes 41 are simultaneously formed with the arrangement shown in FIG.16 (d). In other words, by forming the zigzag along the edge part of the phase shift layer 7b, it becomes possible to arbitrarily set the positional relationships of the fine rectangular holes 41, and various positional relationships other than that shown in FIG.15 (d) becomes possible.

[0074] Next, a description will be given of a fifth embodiment of the pattern exposing method according to the present invention, by referring to FIG.17.

[0075] In this embodiment, a phase shift reticle 6a which is shown in a plan view in FIG.17 (a) is used for the first exposure. This phase shift reticle 6a is made up of a glass substrate 2a, and a plurality of square phase shift layers 7a arranged at predetermined intervals on the glass substrate 2a.

[0076] Then, a phase shift reticle 6b which is shown in a plan view in FIG.17 (b) is used for the second exposure. This phase shift reticle 6b is made up of a glass substrate 2b, and a plurality of square phase shift layers 7b arranged in a checker board pattern on the glass substrate 2b. The square phase shift layers 7b are arranged so that edge parts of the square phase shift layers 7b are perpendicular to edge parts of the square phase shift layers 7a of the phase shift reticle 6a.

[0077] Prior to making the first exposure, a negative resist 39 is formed on the wafer 5, similarly as in the case shown in FIG.12 (b), and the negative resist 39 is patterned by the first exposure using the phase shift reticle 6a shown in FIG.17 (a). As a result, fine space patterns 42 shown in FIG.17 (c) are formed in the negative resist 39 by the edge parts of the phase shift layers 7a.

[0078] Next, prior to making the second exposure, a negative resist 40 is formed on the entire top surface of the wafer 5, similarly as in the case shown in FIG.12 (c), and the negative resist 40 is patterned by the second exposure using the phase shift reticle 6b shown in FIG.17 (b). As a result, fine space patterns 43 shown in FIG.17 (c) are formed in the negative resist 40 by the edge parts of the phase shift layers 7b.

[0079] The fine space patterns 42 and the fine space patterns 43 intersect, and thus, a fine rectangular hole 41 is formed at each intersection of the fine space patterns 42 and 43. In this embodiment, the fine rectangular holes 41 are simultaneously formed with the arrangement shown in FIG.17 (d). In other words, by appropriately selecting the shape of the edge part of the phase shift layers 7a and 7b, it becomes possible to arbitrarily set the positional relationships of the fine rectangular holes 41, and various positional relationships other than that shown in FIG.15 (d) becomes possible.

[0080] Next, a description will be given of a sixth embodiment of the pattern exposing method according to the present invention, by referring to FIGS.18 and 19.

[0081] In this embodiment, a phase shift reticle 6 which is shown in a plan view in FIG.18 (a) is used for the first exposure. This phase shift reticle 6 is made up of a glass substrate 2, and a plurality of zigzag (or sawtooth shaped) phase shift layers 7 extending parallel to each other on the glass substrate 2.

[0082] Then, the same phase shift reticle 6 shown in FIG.18(a) is used for the second exposure by shifting the position of the phase shift reticle 6 in the X direction from the position of the phase shift reticle 6 at the time of the first exposure, as shown in FIG.18 (b). When the phase shift reticle 6 is shifted in this manner, the edge

parts of the phase shift layers 7 during the first exposure intersect perpendicularly to the edge parts of the phase shift layers 7 during the second exposure.

[0083] Prior to making the first exposure, a negative resist 39 is formed on the wafer 5, similarly as in the case shown in FIG.12 (b), and the negative resist 39 is patterned by the first exposure using the phase shift reticle 6 shown in FIG.18 (a). As a result, fine space patterns 42a shown in FIG.19 (a) are formed in the negative resist 39 by the edge parts of the phase shift layers 7.

[0084] Next, prior to making the second exposure, a negative resist 40 is formed on the entire top surface of the wafer 5, similarly as in the case shown in FIG.12 (c). In addition, the same phase shift reticle 6 shown in FIG.18 (a) is shifted in the X direction by a predetermined distance by moving the X-Y stage which carries the wafer 5 and forms a part of the exposure apparatus, for example. As a result, the position of the phase shift reticle 6 which is used for the second exposure is relatively shifted with respect to the position of the phase shift reticle 6 which is used for the first exposure, as shown in FIG.18 (b). In FIG.18 (b), the position of the phase shift reticle 6 used during the first exposure is indicated by a dotted line. Therefore, when the negative resist 40 is patterned by the second exposure using the phase shift reticle 6 shown in FIG.18 (a) which is shifted in position relative to the phase shift reticle 6 used during the first exposure, fine space patterns 42b shown in FIG.19 (a) are formed in the negative resist 40 by the edge parts of the phase shift layers 7.

[0085] The fine space patterns 42a and the fine space patterns 42b intersect, and thus, a fine rectangular hole 41 is formed at each intersection of the fine space patterns 42a and 42b. In this embodiment, the fine rectangular holes 41 are simultaneously formed with the arrangement shown in FIG.19 (b). In other words, by appropriately selecting the shape of the edge part of the phase shift layers 7 and appropriately shifting the position of the phase shift reticle 6 between the first and second exposures, it becomes possible to arbitrarily set the positional relationships of the fine rectangular holes 41, and various positional relationships other than that shown in FIG.15 (d) becomes possible.

[0086] According to this embodiment, there is an additional advantage in that the plurality of fine rectangular holes 41 can be formed simultaneously using only one kind of phase shift reticle 6. As a result, there is no need to change the phase shift reticle 6 between the first and second exposures, and the throughput of the lithography process is improved compared to the other embodiments.

[0087] In the first through sixth embodiments, it is of course not essential for the edge part of the phase shift layer of the phase shift reticle which is used during the first exposure to intersect perpendicularly to the edge part of the phase shift layer of the phase shift reticle which is used during the second exposure. As long as the edge parts intersect, it is possible to form a fine hole. In other words, it is possible to form fine holes having an arbitrary shape other than the rectangular shape.

[0088] Therefore, according to the first through sixth embodiments, it is possible to form an extremely fine hole which exceeds the resolution limit of the imaging optical system and could not be formed by the conventional techniques. The contrast is particularly good according to these embodiments, because one resist layer is formed exclusively for each exposure. In other words, if a single resist layer were subjected to both the first and second exposures, the contrast of the hole which is formed would deteriorate by approximately 50%, and the edges of the formed hole would become rounded. However, such a contrast deterioration will not occur according to these embodiments, and it is possible to form a fine hole having the designed shape with a high accuracy.

Claims

1. A pattern exposing method for forming a predetermined resist pattern (41, 42, 42A) on a substrate (5), comprising the steps of

   (a) exposing a first resist layer (39) which is formed on said substrate (5) using a first reticle (6) which includes a first pattern for exposing a first corresponding pattern on said first resist layer (39) by use of a phase shift of light transmitted through said first reticle (6);
   (b) developing said exposed first resist layer (39);
   (c) forming a second resist layer (40) on the entire surface of said substrate (5) including a top of said first resist layer (39);
   (d) exposing said second resist layer (40) using a second reticle (6) which has a second pattern for exposing a second corresponding pattern on said second resist layer (40) by use of a phase shift of light transmitted through said second reticle (6), said second corresponding pattern overlapping at least a part of said first corresponding pattern; and
   (e) developing said second resist layer (40) so that a part of said first corresponding pattern is removed by said second corresponding pattern and the predetermined resist pattern (41, 42, 42A) is formed.

2. A pattern exposing method according to claim 1, **characterized in that**

   said step (a) uses a first reticle (6) which has said first pattern which is defined by a phase shift layer (7) formed on a transparent reticle substrate (2), and exposes said first corresponding pattern on said first resist layer (39)

using an edge part of said phase shift layer (7).

3. A pattern exposing method according to claim 2, **characterized in that**

said step (d) uses a second reticle (6) which has said second pattern which is defined by a phase shift layer (7) formed on a transparent reticle substrate (2), and exposes said first corresponding pattern on said second resist layer (40) using an edge part of said phase shift layer (7).

4. A pattern exposing method according to claim 1 or 2, **characterized in that**

said first corresponding pattern at least includes a first part which intersects perpendicularly to a second part of said second corresponding pattern on said substarte (5).

5. A pattern exposing method according to claim 4, **characterized in that**

said first and second parts of said first and second corresponding patterns have an oblong shape.

6. A pattern exposing method according to claim 5, **characterized in that**

said first and second parts have zigzag contours.

7. A pattern exposing method according to any one of claims 1 to 6, **characterized in that**

said steps (a) and (c) use a negative resist as said first and second resist layers (39, 40).

8. A pattern exposing method according to claim 7, **characterized in that**

said predetermined resist pattern formed by said step (e) corresponds to a hole (41).

9. A pattern exposing method according to any one of claims 1 to 8, **characterized in that**

said first and second reticles (6) used by said steps (a) and (d) are identical and include phase shift patterns which are shifted laterally relative to one another between the two independet exposures made in said steps (a) and (d).

10. A pattern exposing method according to claim 1, **characterized in that**

said step (a) uses a first reticle (6) which has said first pattern which is defined by a phase shift layer (7) formed on a transparent reticle substrate (2) and having first and second phase shift parts, and exposes said first corresponding pattern on said first resist layer (39) using edge parts of said first and second phase shift parts,
said first phase shift part having a width such that a closed ring pattern is exposed by said edge parts thereof, and
said second phase shift part having a width narrower than that of said first phase shift part so that patterns exposed by said edge parts thereof overlap in the form of a single line pattern.

Patentansprüche

1. Belichtungsverfahren zur Erzeugung eines vorbestimmten Resistmusters (41, 42, 42A) auf einem Substrat (5), mit den Verfahrensschritten:

(a) Belichten einer auf dem Substrat (5) ausgebildeten ersten Resistschicht (39), wobei ein erstes Reticle (6) benutzt wird, das ein erstes Muster enthält zum Belichten eines ersten korrespondierenden Musters auf die erste Resistschicht (39) unter Anwendung einer Phasenverschiebung des durch das erste Reticle (6) übertragenen Lichts,
(b) Entwickeln der belichteten ersten Besistschicht (39),
(c) Ausbilden einer zweiten Resistschicht (40) auf der gesamten Fläche des Substrats (5), einschließlich der Oberseite der ersten Resistschicht (39),
(d) Belichten der zweiten Resistschicht (40), wobei ein zweites Reticle (6) benutzt wird, das ein zweites Muster enthält zum Belichten eines zweiten korrespondierenden Musters auf die zweite Resistschicht (40) unter Anwendung einer Phasenverschiebung des durch das zweite Reticle (6) übertragenen Lichts, wobei das zweite korrespondierende Muster zumindest einen Teil des ersten korrespondierenden Musters überlappt, und
(e) Entwickeln der zweiten Resistschicht (40) in der Weise, daß ein Teil des ersten korrespondierenden Musters durch das zweite korrespondierende Muster entfernt wird und das vorbestimmte Resistmuster (41, 42, 42A) gebildet wird.

2. Belichtungsverfahren nach Anspruch 1,

dadurch gekennzeichnet,

daß in dem Verfahrensschritt (a) ein erstes Reticle (6) benutzt wird mit einem ersten Muster, das durch eine auf einem transparenten Reticlesubstrat (2) ausgebildete Phasenverschiebungsschicht (7) definiert ist, wobei das erste korrespondierende Muster unter Benutzung eines Kantenabschnitts der Phasenverschiebungsschicht (7) auf die erste Resistschicht (39) belichtet wird.

3. Belichtungsverfahren nach Anspruch 2, dadurch gekennzeichnet,

daß in dem Verfahrensschritt (d) ein zweites Reticle (6) benutzt wird mit dem genannten zweiten Muster, das durch eine auf einem transparenten Reticlesubstrat (2) ausgebildete Phasenverschiebungsschicht (7) definiert ist, wobei das erste korrespondierende Muster unter Benutzung eines Kantenabschnitts der Phasenverschiebungsschicht (7) auf die zweite Resistschicht (40) belichtet wird.

4. Belichtungsverfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet,

daß das erste korrespondierende Muster zumindest einen ersten Teil enthält, der einen zweiten Teil des zweiten korrespondierenden Musters auf dem Substrats (5) in senkrechter Richtung schneidet.

5. Belichtungsverfahren nach Anspruch 4, dadurch gekennzeichnet,

daß der erste und der zweite Teil des ersten und des zweiten korrespondierenden Musters eine längliche Form haben.

6. Belichtungsverfahren nach Anspruch 5, dadurch gekennzeichnet,

daß der erste und der zweite Teil Zickzackkonturen haben.

7. Belichtungsverfahren nach einem der Ansprüche 1 bis 6, dadurch gekennzeichnet,

daß in den Verfahrensschritten (a) und (c) als erste und zweite Resistschicht (39, 40) ein Negativresist verwendet wird.

8. Belichtungsverfahren nach Anspruch 7, dadurch gekennzeichnet,

daß die durch den Verfahrensschritt (e) gebildeten vorbestimmten Resistmuster einem Loch (41) entsprechen.

9. Belichtungsverfahren nach einem der Ansprüche 1 bis 8, dadurch gekennzeichnet,

daß das erste und das zweite Reticle (6), die in den Verfahrensschritten (a) und (d) verwendet werden, identisch sind und Phasenverschiebungsmuster aufweisen, die zwischen den zwei unabhängigen Belichtungen, die in den Verfahrensschritten (a) und (d) ausgeführt werden, relativ zueinander seitlich verschoben werden.

10. Belichtungsverfahren nach Anspruch 1, dadurch gekennzeichnet,

daß in dem Verfahrensschritt (a) ein erstes Reticle (6) benutzt wird, das das erste Muster aufweist, das durch eine Phasenverschiebungsschicht (7) definiert ist, die auf einem transparenten Reticlesubstrat (2) ausgebildet ist und erste und zweite Phasenverschiebungsteile aufweist, und das erste korrespondierende Muster unter Benutzung von Kantenabschnitten des ersten und des zweiten Phasenverschiebungsteils auf die erste Resistschicht (9) belichtet wird,
daß der erste Phasenverschiebungsteil eine solche Breite hat, daß durch seine genannten Kantenabschnitten ein geschlossenes Ringmuster belichtet wird,
und daß der zweite Phasenverschiebungsteil eine geringere Breite hat als der erste Phasenverschiebungsteil, so daß Muster, die mit Hilfe der Kantenabschnitte belichtet werden, in Form eines einzigen Linienmusters einander überlappen.

Revendications

1. Procédé d'exposition de motif permettant de former un motif de résist prédéterminé (41, 42, 42A) sur un substrat (5), comprenant les opérations suivantes :

(a) exposer une première couche de résist (39), qui est formée sur ledit substrat (5), en utilisant un premier réticule (6) qui comporte un premier motif permettant d'exposer un premier motif correspondant sur ladite première couche de résist (39) en utilisant un déplacement de phase de la lumière transmise au travers dudit premier réticule (6) ;
(b) développer ladite première couche de résist exposée (39) ;

(c) former une deuxième couche de résist (40) sur toute la surface dudit substrat (5) y compris sur le dessus de ladite première couche de résist (39) ;

(d) exposer ladite deuxième couche de résist (40) en utilisant un deuxième réticule (6), qui possède un deuxième motif, afin d'exposer un deuxième motif correspondant sur ladite deuxième couche de résist (40) en utilisant un déplacement de phase de la lumière transmise au travers dudit deuxième réticule (6), ledit deuxième motif correspondant étant en chevauchement avec au moins une partie dudit premier motif correspondant ; et

(e) développer ladite deuxième couche de résist (40) de façon qu'une partie dudit premier motif correspondant soit retirée par ledit deuxième motif correspondant et que le motif de résist prédéterminé (41, 42, 42A) soit formé.

2. Procédé d'exposition de motif selon la revendication 1, caractérisé en ce que ladite opération (a) utilise un premier réticule (6) qui possède ledit premier motif qui est défini par une couche de déplacement de phase (7) formée sur un substrat de réticule transparent (2) et expose ledit premier motif correspondant sur ladite première couche de résist (39) en utilisant une partie de bord de ladite couche de déplacement de phase (7).

3. Procédé d'exposition de motif selon la revendication 2, caractérisé en ce que ladite opération (d) utilise un deuxième réticule (6) qui possède ledit deuxième motif qui est défini par une couche de déplacement de phase (7) formée sur un substrat de réticule transparent (2) et expose ledit premier motif correspondant sur ladite deuxième couche de résist (40) en utilisant une partie de bord de ladite couche de déplacement de phase (7).

4. Procédé d'exposition de motif selon la revendication 1 ou 2, caractérisé en ce que ledit premier motif correspondant comporte au moins une première partie qui coupe perpendiculairement une deuxième partie dudit deuxième motif correspondant sur ledit substrat (5).

5. Procédé d'exposition de motif selon la revendication 4, caractérisé en ce que lesdites première et deuxième parties desdits premier et deuxième motifs correspondants ont une forme allongée.

6. Procédé d'exposition de motif selon la revendication 5, caractérisé en ce que lesdites première et deuxième parties ont des contours en zigzag.

7. Procédé d'exposition de motif selon l'une quelconque des revendications 1 à 6, caractérisé en ce que lesdites opérations (a) et (c) utilisent un résist négatif au titre desdites première et deuxième couches de résist (39, 40).

8. Procédé d'exposition de motif selon la revendication 7, caractérisé en ce que ledit motif de résist prédéterminé formé par ladite opération (e) correspond à un trou (41).

9. Procédé d'exposition de motif selon l'une quelconque des revendications 1 à 8, caractérisé en ce que lesdits premier et deuxième réticules (6) utilisés par lesdites opérations (a) et (d) sont identiques et comportent des motifs de déplacement de phase qui sont déplacés latéralement les uns par rapport aux autres entre les deux expositions indépendantes effectuées lors desdites opérations (a) et (d).

10. Procédé d'exposition de motif selon la revendication 1, caractérisé en ce que ladite opération (a) utilise un premier réticule (6) qui possède ledit premier motif qui est défini par une couche de déplacement de phase (7) formée sur un substrat de réticule transparent (2) et ayant des première et deuxième parties de déplacement de phase et expose ledit premier motif correspondant sur ladite première couche de résist (39) en utilisant des parties de bord desdites première et deuxième parties de déplacement de phase, ladite première partie de déplacement de phase ayant une largeur telle qu'un motif en anneau fermé est exposé par lesdites parties de bord de celle-ci, et ladite deuxième partie de déplacement de phase possédant une largeur plus étroite que celle de ladite première partie de déplacement de phase de sorte que les motifs exposés par lesdites parties de bord de celles-ci se chevauchent en prenant la forme d'un unique motif de ligne.

FIG. 1

(a)

(b)

(c)

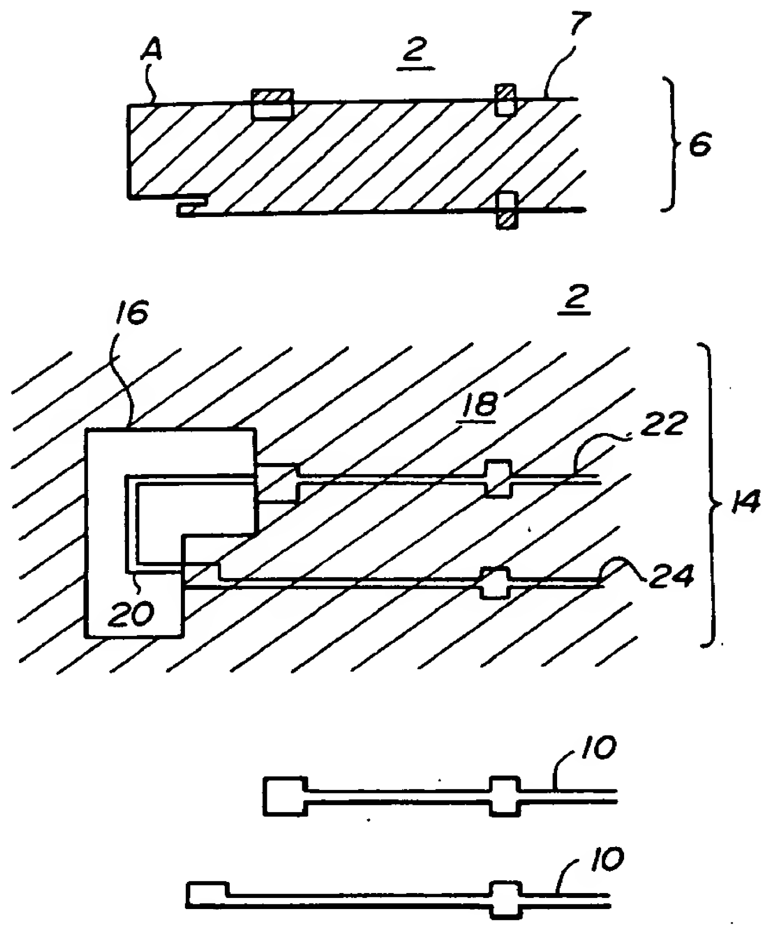


FIG.2 PRIOR ART

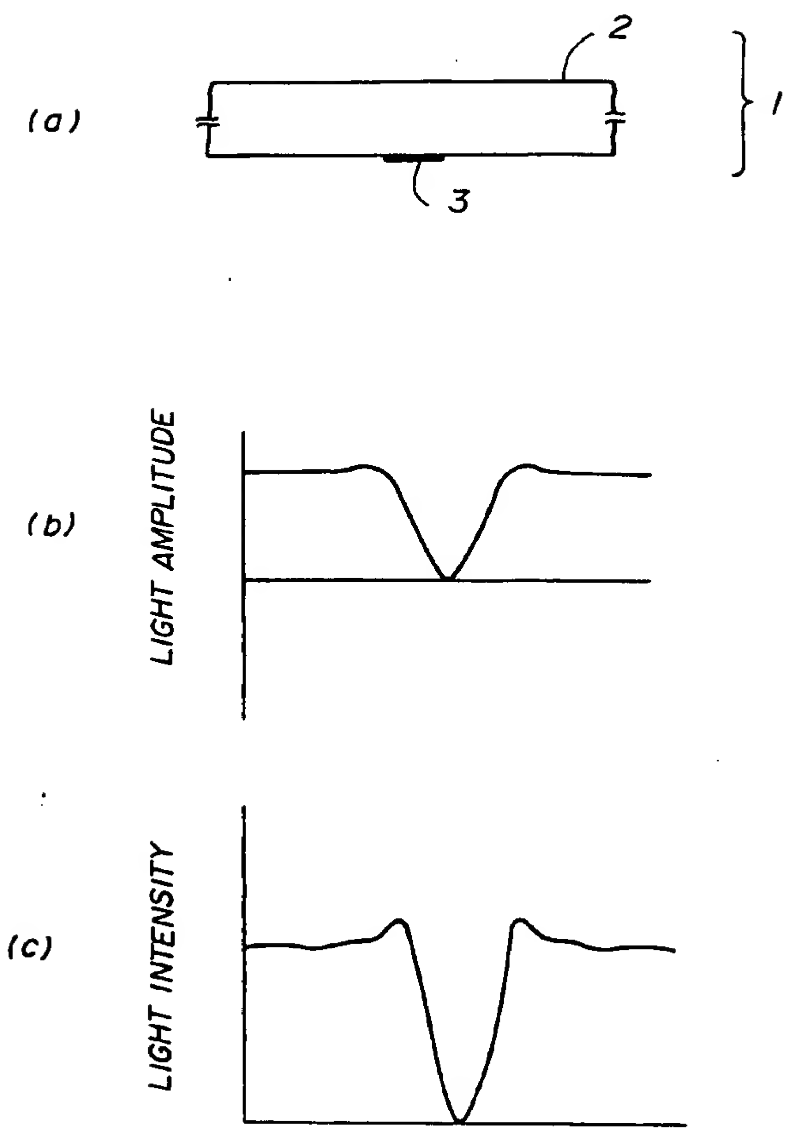


FIG. 3 PRIOR ART

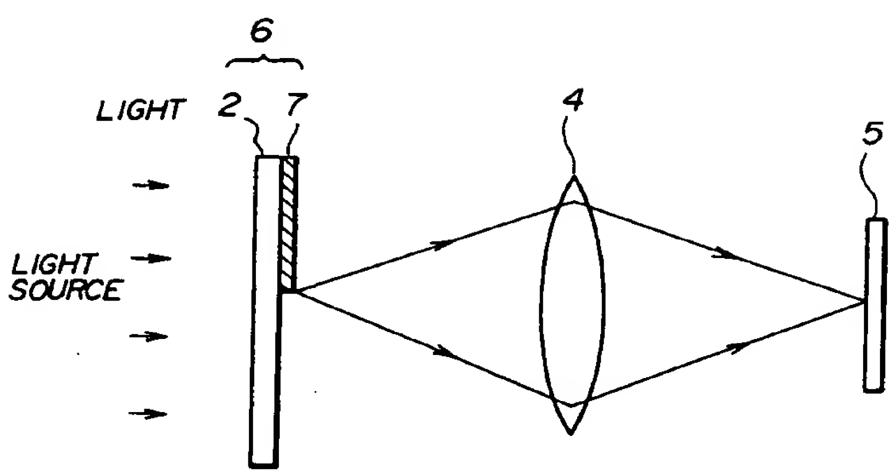


FIG.4

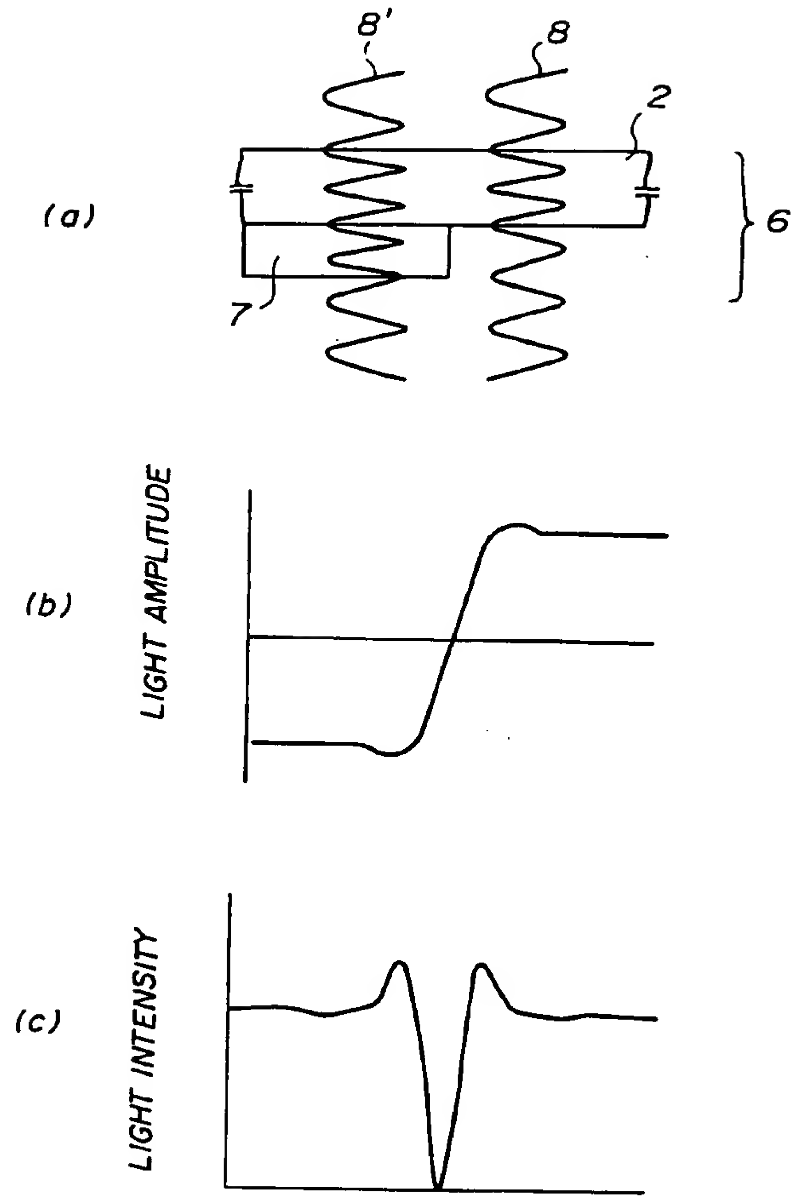


FIG.5 PRIOR ART

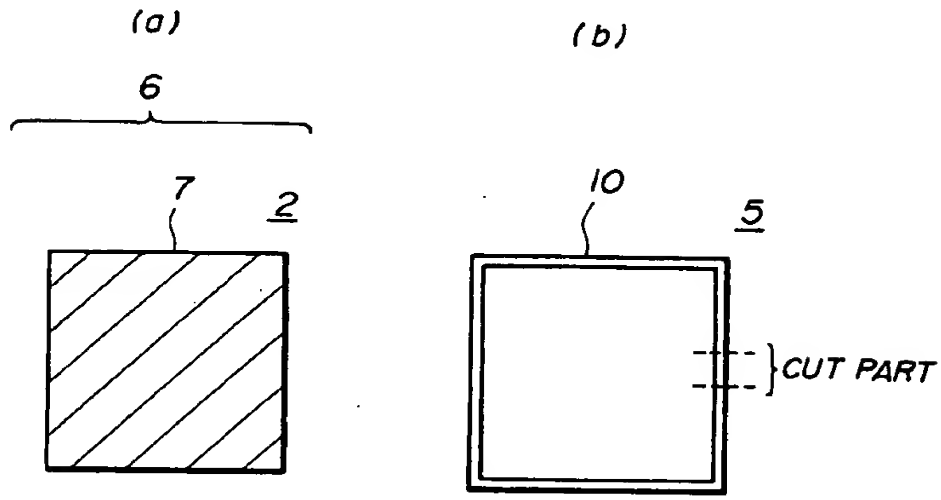


FIG.6 PRIOR ART

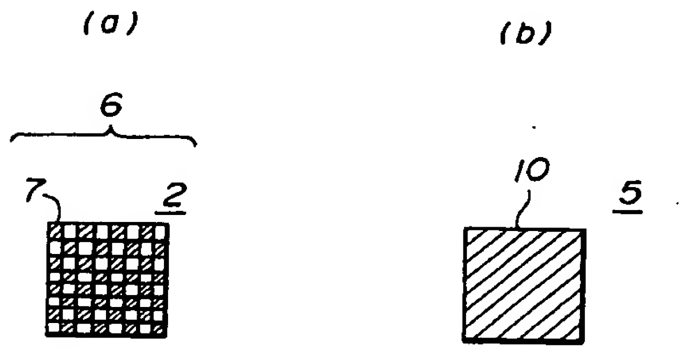


FIG. 7

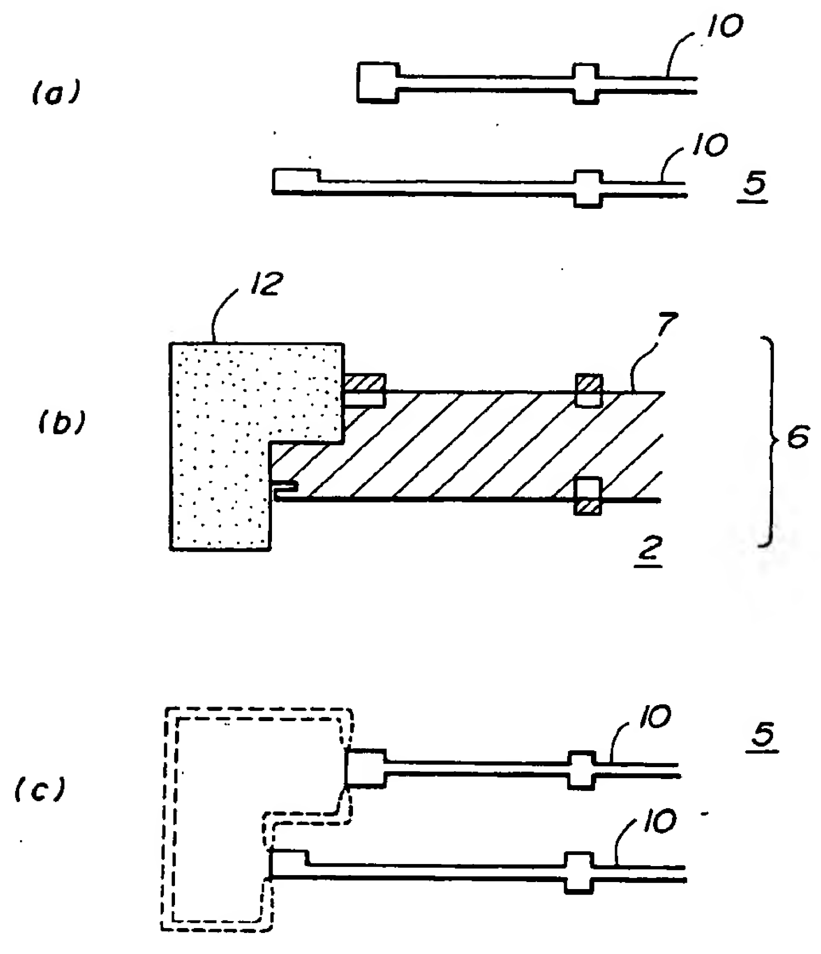


FIG. 8 PRIOR ART

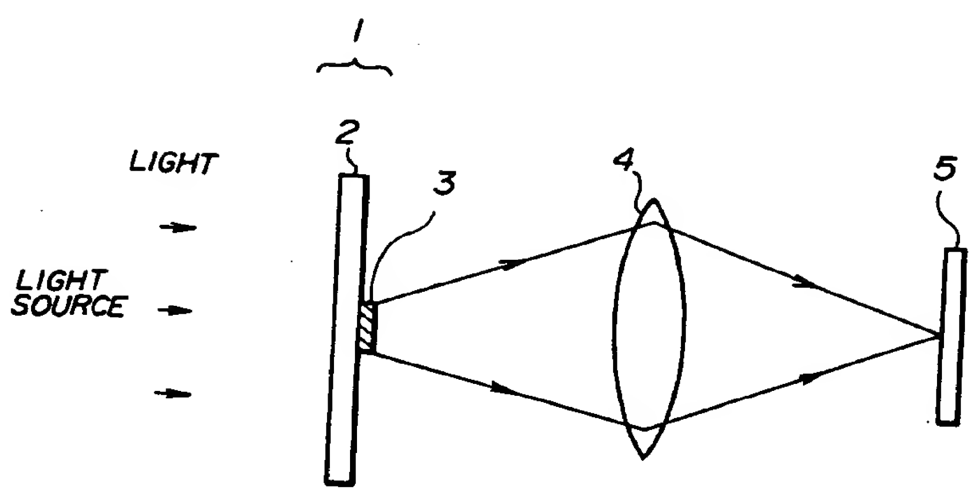


FIG.9

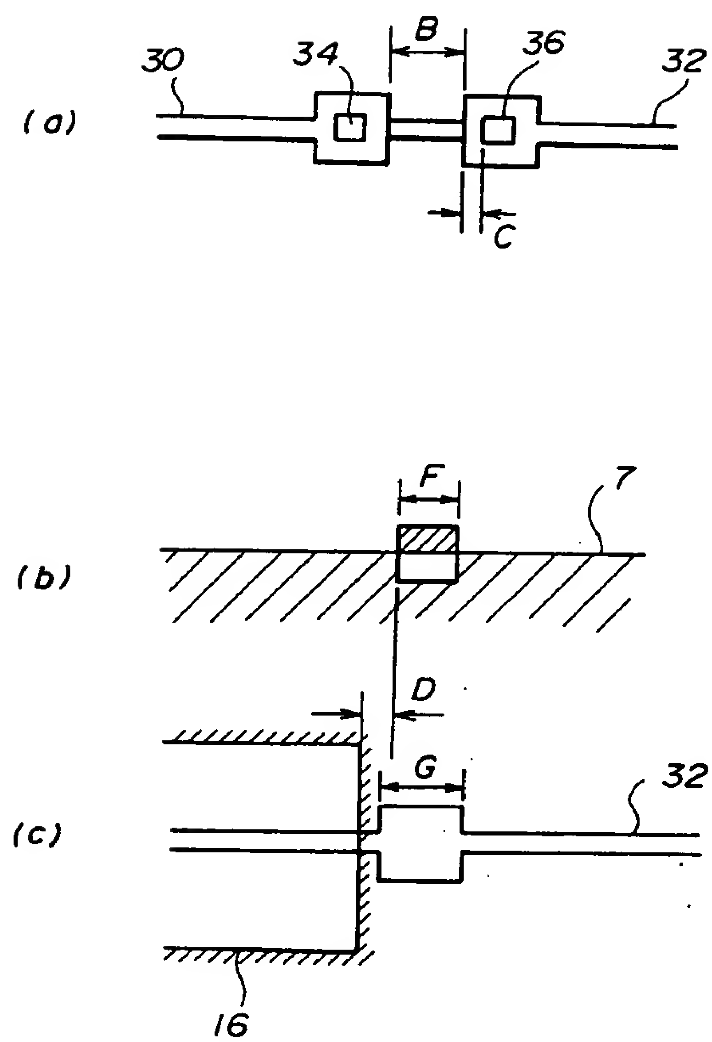


FIG. 10

(a)

(b)

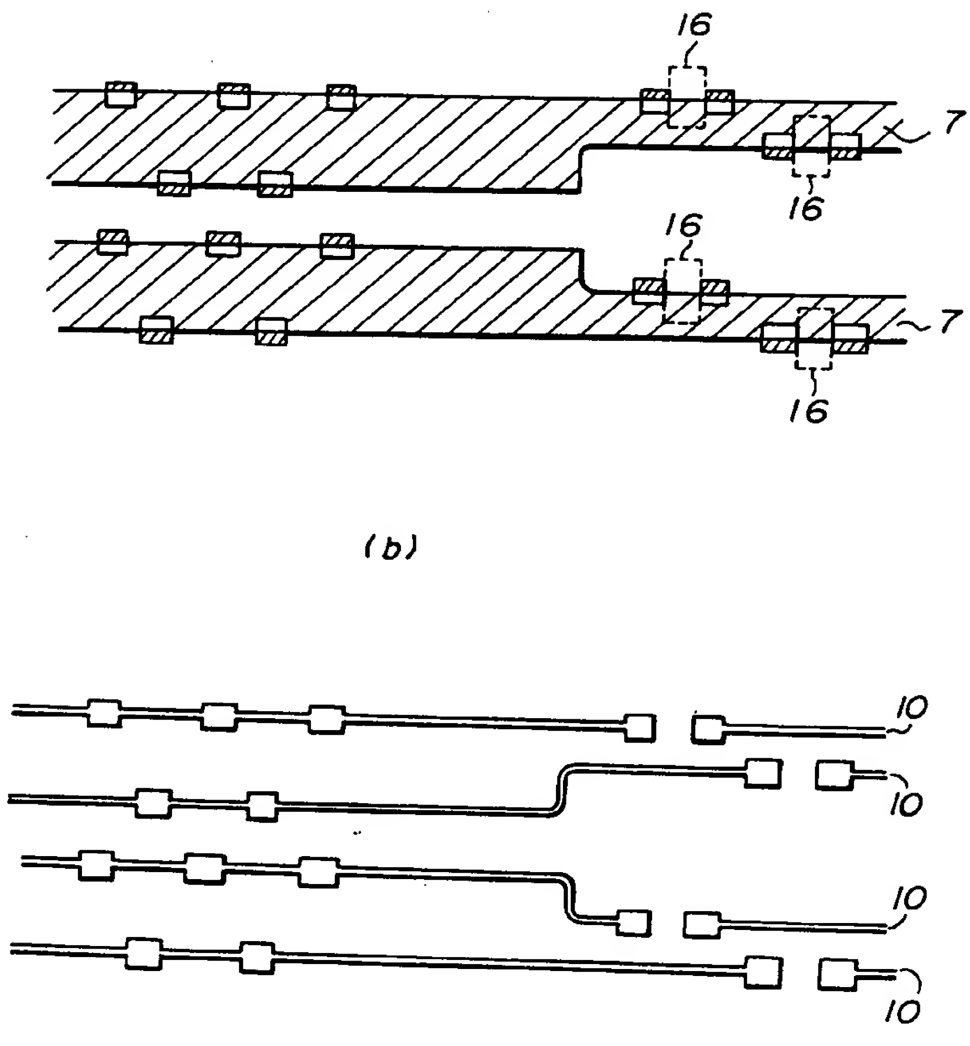
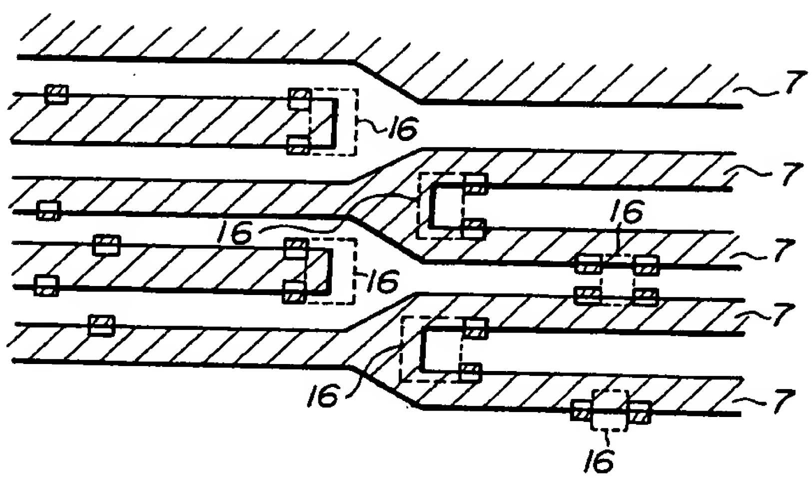


FIG. 11

(a)



(b)

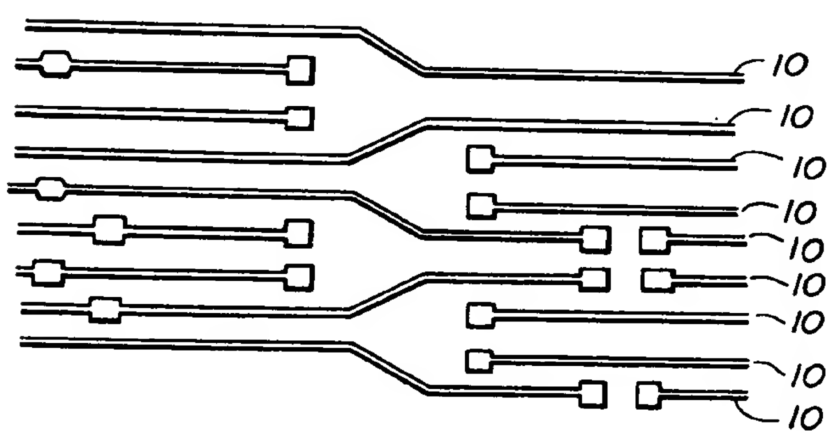


FIG.12

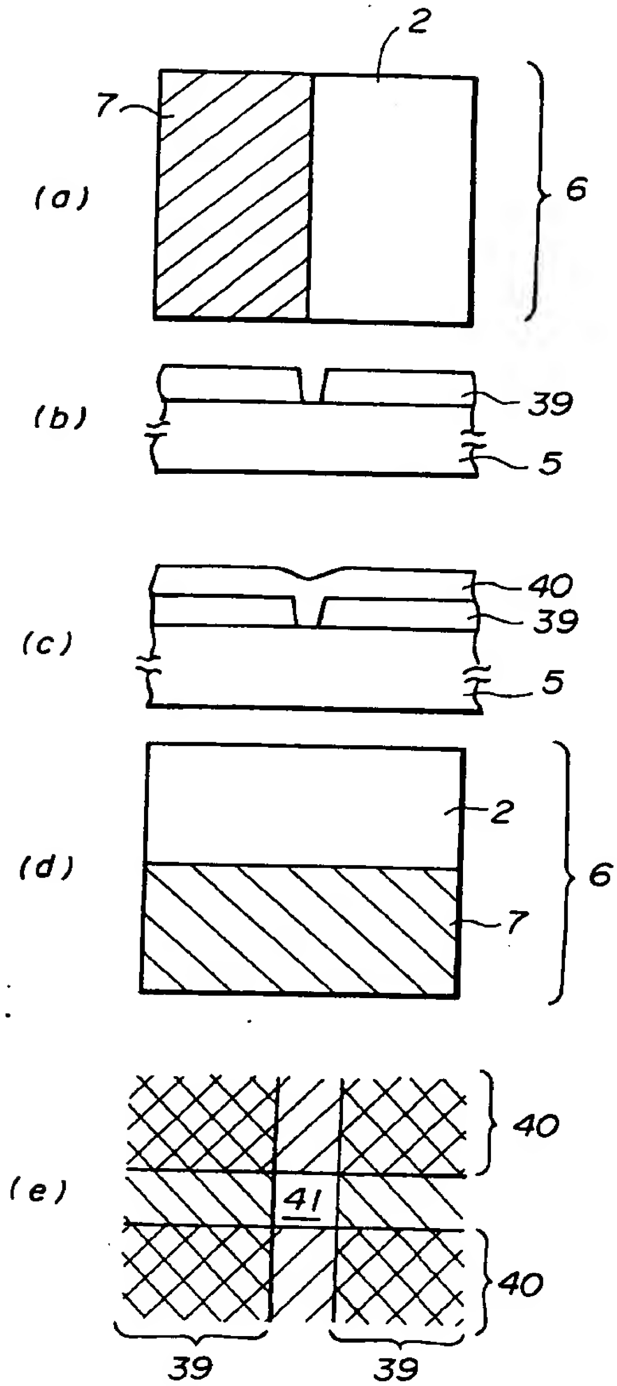
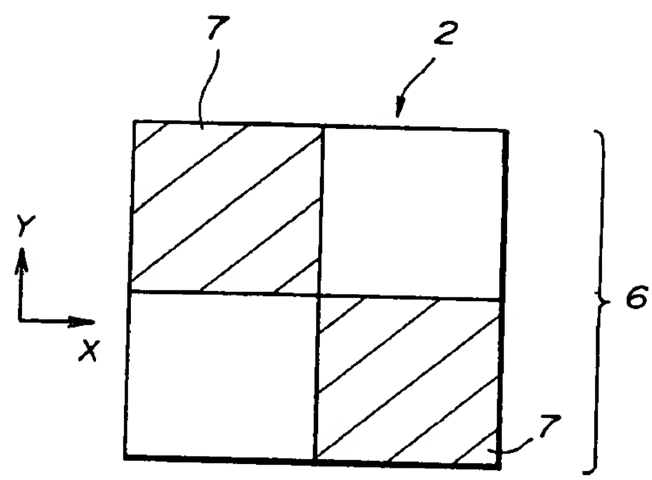


FIG. 13

(a)



(b)

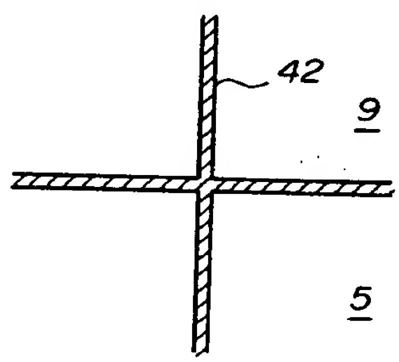


FIG.14

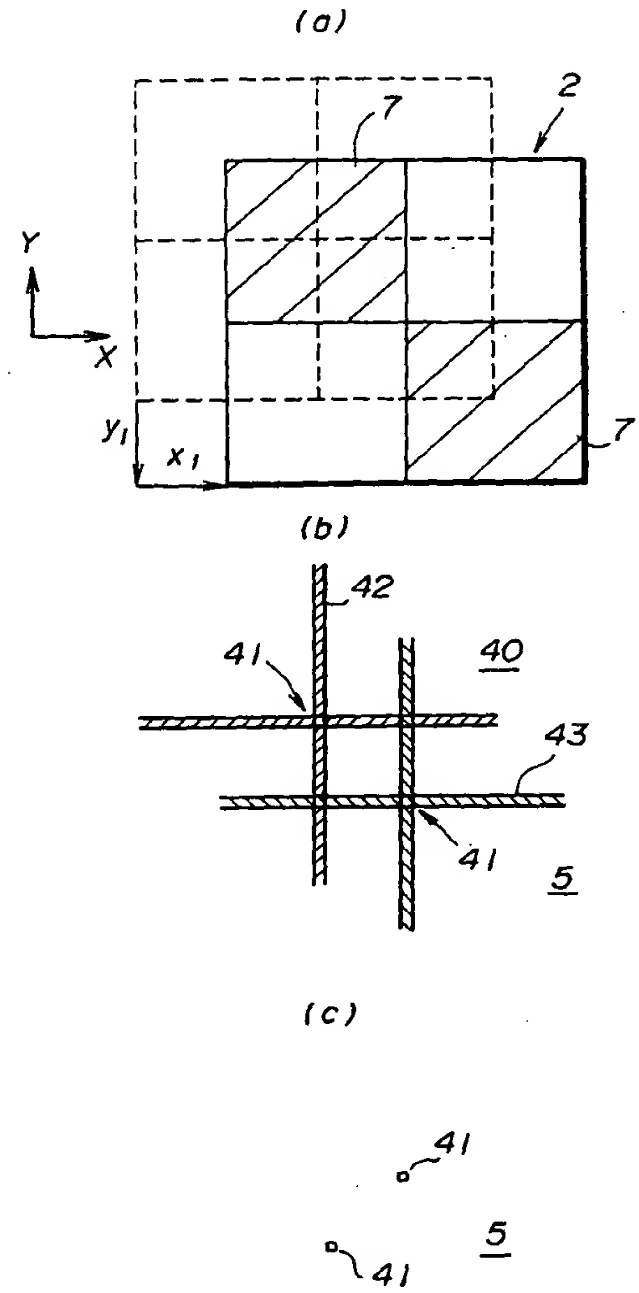


FIG.15

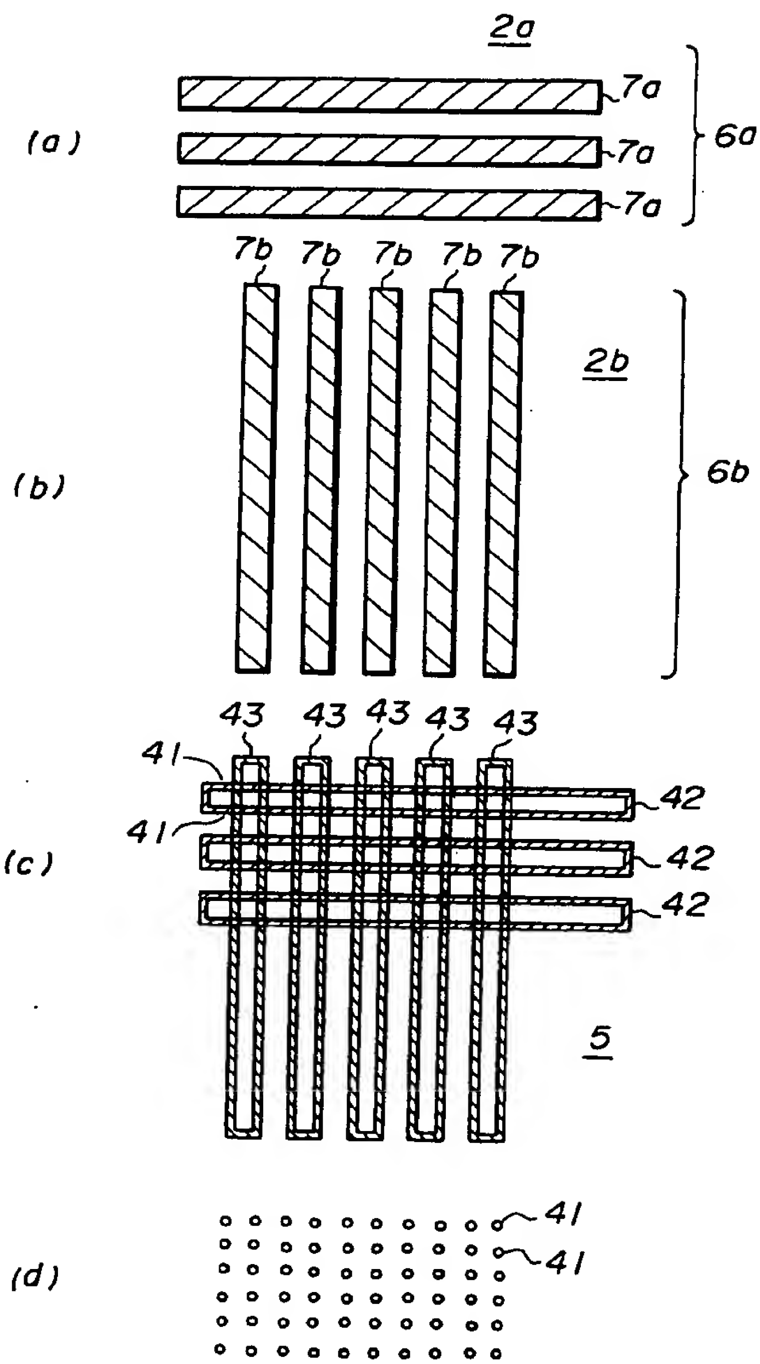

2a
7a
7a
7a
6a
(a)
7b
7b
7b
7b
7b
2b
6b
(b)
43
43
43
43
43
41
41
42
42
42
(c)
5
41
41
(d)

FIG.16

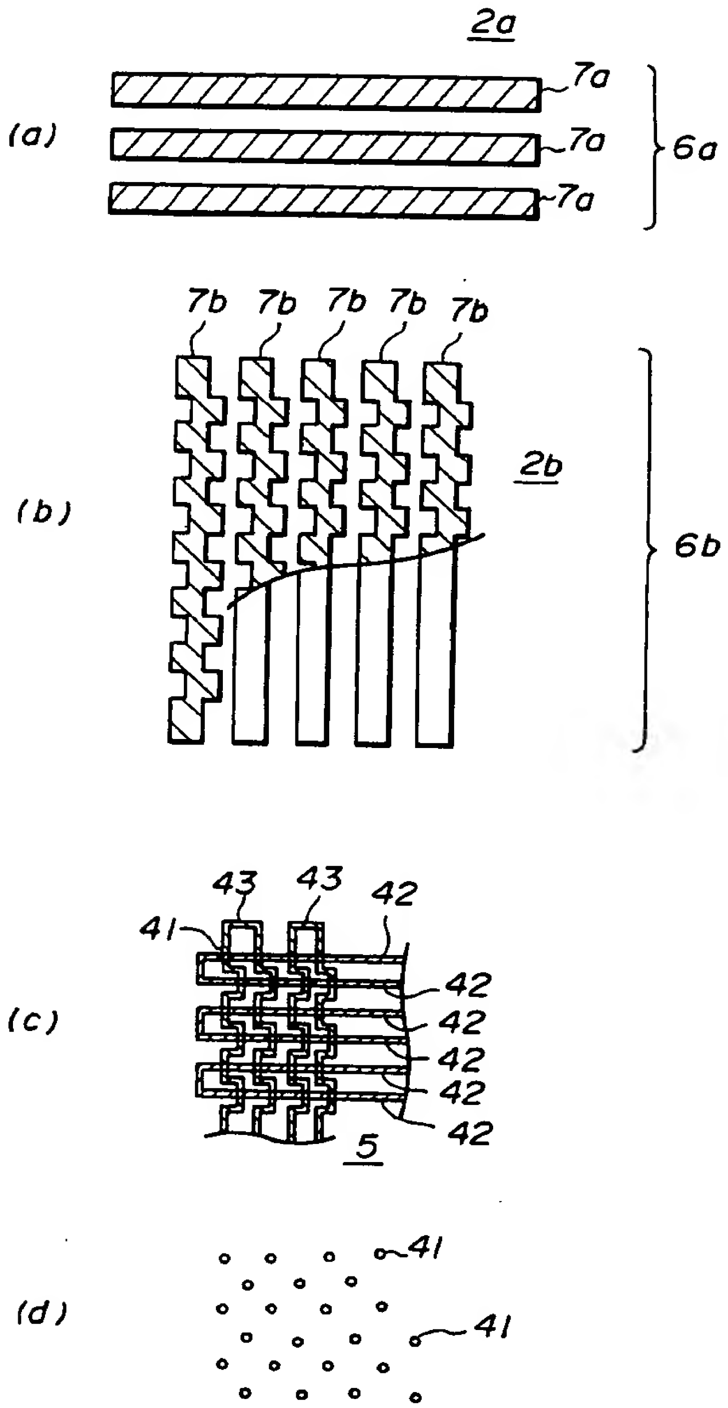

2a
(a)
7a
7a
7a
6a
7b
7b
7b
7b
7b
(b)
2b
6b
43
43
42
41
(c)
42
42
42
42
42
5
(d)
41
41

FIG. 17

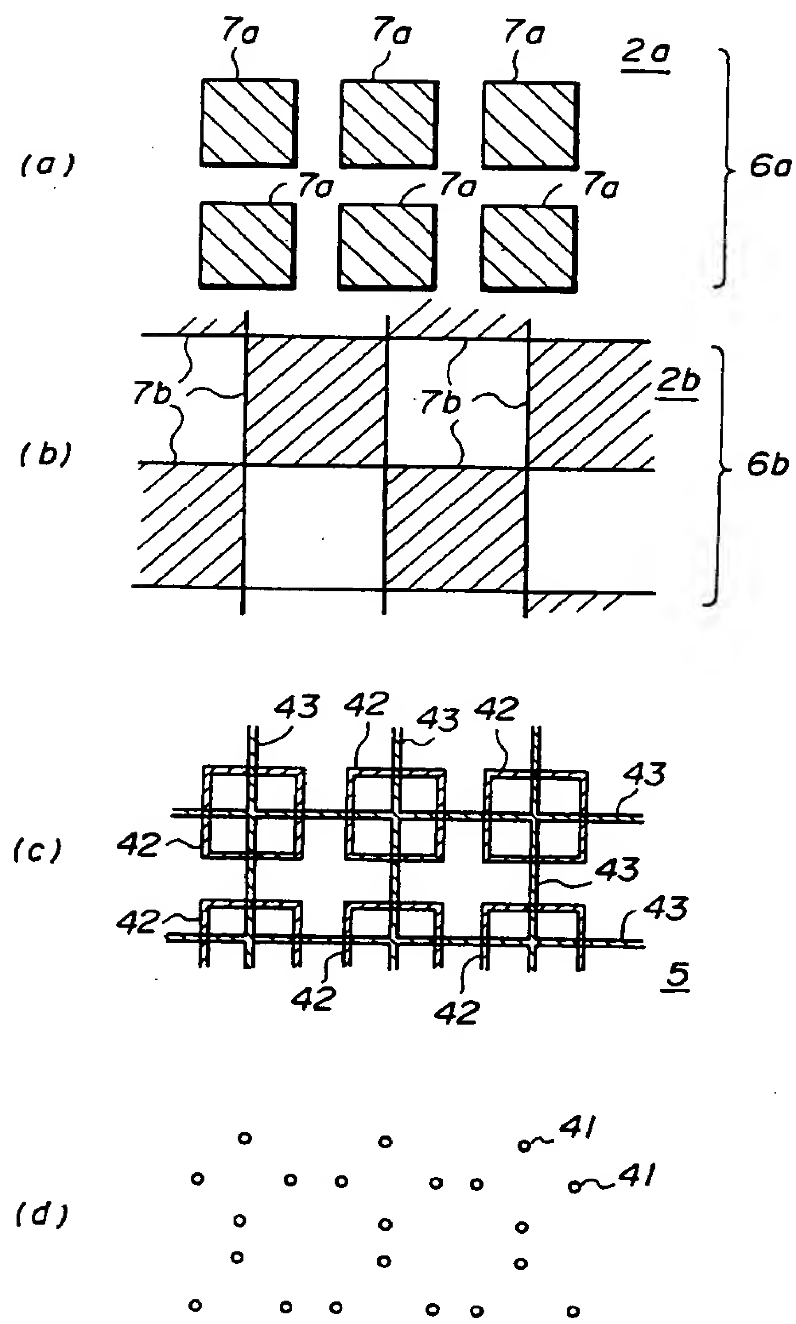
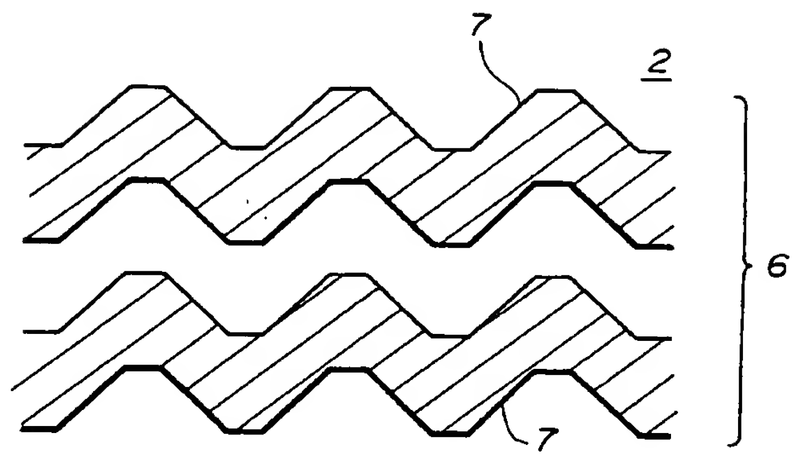


FIG.18

(a)



(b)

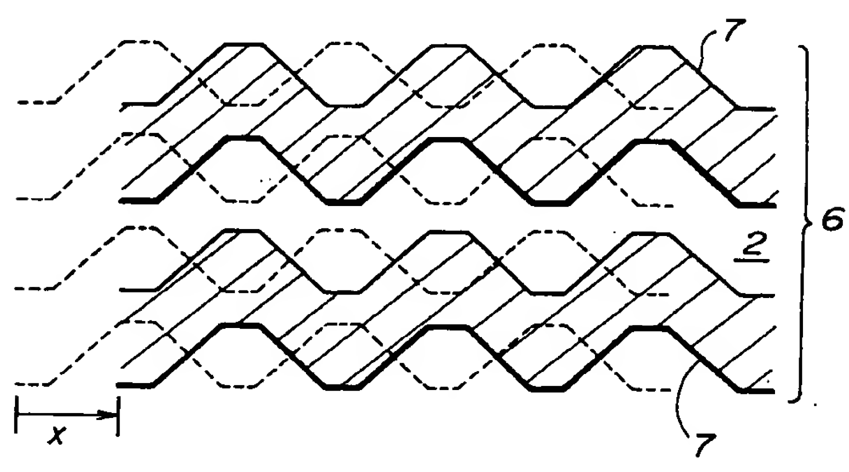


FIG.19